PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 15992-WO-03+	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/IL2004/000573	International filing date *(day/month/year)* 28.06.2004	Priority date *(day/month/year)* 02.07.2003
International Patent Classification (IPC) or national classification and IPC H01L31/101		
Applicant SEMI-CONDUCTOR DEVICES - AN ELBIT SYSTEMS - ...		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 5 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 6 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the opinion
☐	Box No. II	Priority
☐	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☐	Box No. VII	Certain defects in the international application
☐	Box No. VIII	Certain observations on the international application

Date of submission of the demand	Date of completion of this report
26.04.2005	02.09.2005
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Boero, M Telephone No. +31 70 340-4308

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/IL2004/000573

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1-33 as originally filed

Claims, Numbers

1-31 filed with telefax on 26.04.2005

Drawings, Sheets

1/16-16/16 as originally filed

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-31
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-31
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-31
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Reference is made to the following documents:

D1: PARK J ET AL: "Reduction of dark current in an n-type In0.3Ga0.7As/GaAs quantum well infrared photodetector by using a camel diode structure" SOLID STATE ELECTRONICS, ELSEVIER SCIENCE PUBLISHERS, BARKING, GB, vol. 46, no. 5, May 2002 (2002-05), pages 651-654, XP004346693 ISSN: 0038-1101

D2: US-A-4 740 819 (KAWATA MASAHIKO ET AL) 26 April 1988 (1988-04-26)

The application does not meet the requirements of Article 6 PCT, because claim 1 is not clear. The expression "when biased with an externally applied voltage, the bands in the photon absorbing layer next to the barrier layer...." discloses a condition that stems from the way the photodetector is operated and not from its intrinsic properties, hence the subject-matter for which protection is sought appears to be unclear.

The above objection notwithstanding, the subject-matter of claim 1 specifies that the bands in the photon absorbing layer next to the barrier layer are flat or accumulated, and the flat part of the valence band edge of the photon adsorbing layer lies below the flat part of the valence band edge of the contact layer and it also lies an energy of no more than 10KTop above the valence band edge in any part of the barrier layer. This feature is neither known nor rendered obvious by the disclosures of the closest prior art, D1 and D2. Hence the subject matter of claim 1 appears to be novel and inventive in the sense of Art. 33(2)(3) PCT.

The subject-matter of claims 2-12, is directly or indirectly dependent upon claim 1 and consequently is also novel and inventive in the sense of Art. 33(2)(3) PCT.

The subject-matter of claims 13-31 discloses either essentially the same subject-matter of claims 1-12 or straightforward applications of the device of claim 1, and consequently appears to be also novel and inventive.

CLAIMS

1. A photo-detector with a reduced G-R noise, comprising a sequence of a p-type contact layer, a middle barrier layer and an n-type photon absorbing layer, said middle barrier layer having an energy bandgap at least twice that of the photon absorbing layer, there being no layer with a narrower energy bandgap than that in the photon-absorbing layer, wherein under flat band conditions the valence band edge of the contact layer lies below its own conduction band edge, or below the conduction band edge of the barrier layer, by at least twice the bandgap energy of the photon absorbing layer and, wherein when biased with an externally applied voltage, the bands in the photon absorbing layer next to the barrier layer are flat or accumulated, and the flat part of the valence band edge of the photon absorbing layer lies below the flat part of the valence band edge of the contact layer and it also lies an energy of not more than $10kT_{op}$ above the valence band edge in any part of the barrier layer, where k is the Boltzman constant and T_{op} is the operating temperature.
2. A photo-detector according to claim 1 wherein the photon absorbing layer has a typical thickness of 1-10μ and doping of n $<10^{16}$ cm^{-3}.
3. A photo-detector according to claim 1 wherein the middle barrier layer has a thickness of between 0.05 and 1μm.
4. A photo-detector according to claim 1 wherein the barrier layer is doped n-type, typically n $< 5 \times 10^{16}$ cm^{-3}, and a p-n junction is formed between said barrier layer and a p-type, p $< 5\times10^{18}$ cm^{-3}, contact layer.
5. A photo-detector according to claim 1 wherein the barrier layer is doped p-type, typically p $< 5 \times 10^{16}$ cm^{-3} and a p-n junction is formed between said barrier

layer and an n-type δ–doping layer typically with $5\times10^{10} < n < 10^{12}$ donors cm^{-2} included at the edge of the photon absorbing layer next to the barrier layer.

6. A photo-detector according to claim 1 wherein the barrier layer is low-doped p-type, typically $p < 10^{15}$ cm^{-3}, and a p-n junction is formed between said barrier layer and the n-type photon absorbing layer.

7. A photo-detector according to claim 1, wherein the photon absorbing layer is an $InAs_{1-x}Sb_x$ alloy.

8. A photo-detector according to claim 1 wherein the photon absorbing layer is a type II superlattice material which comprises alternating sub-layers of $InAs_{1-w}Sb_w$ and $Ga_{1-x-y}In_xAl_ySb_{1-z}As_z$ with $0\leq w \leq 1$, $0\leq x \leq 1$, $0\leq y \leq 1$, $0\leq z \leq 1$ and $x + y < 1$ and wherein the sub-layers each have a thickness in the range of 0.6-10 nm.

9. A photo-detector according to claim 1 wherein the contact layer is GaSb.

10. A photo-detector according to claim 1, wherein the contact layer is a type II superlattice comprising alternating sub-layers of $InAs_{1-w}Sb_w$ and $Ga_{1-x-y}In_xAl_ySb_{1-z}As_z$ with $0\leq w \leq 1$, $0\leq x \leq 1$, $0\leq y \leq 1$, $0\leq z \leq 1$ and $x + y < 1$ and wherein the sub-layers have a thickness in the range of 0.6-10 nm.

11. A photo-detector according to claim 1 wherein the middle barrier layer is a $Ga_{1-x}Al_xSb_{1-y}As_y$ alloy with $0\leq x \leq 1$ and $0\leq y \leq 1$.

12. A photo-detector according to claim 1 in which the n-type photon absorbing layer is terminated by a highly n-doped terminating layer, typically with $3 \times 10^{17} < n < 3 \times 10^{18}$ donors cm^{-3}, and with thickness 0.5 - 4μ, so that the valence band edge of said highly n-doped terminating layer lies below that of the n-type photon absorbing layer.

13. A photo-detector comprising stacked detector sub-units as in claim 7 or claim 12 in which each detector sub-unit may have a different cut-off wavelength and in which each detector sub-unit is separated from its neighboring sub-unit by a p-type GaSb layer to which an external contact may be made.

14. A photo-detector with a reduced G-R noise, comprising a sequence of a p-type contact layer, a middle barrier layer and an n-type photon absorbing layer, said middle barrier layer having an energy bandgap significantly larger than that of the photon absorbing layer, there being no layer with a narrower energy bandgap than that in the photon-absorbing layer, wherein under flat band conditions the valence band edge of the contact layer lies below its own conduction band edge, or below the conduction band edge of the barrier layer, by significantly more than the bandgap energy of the photon absorbing layer and, wherein when biased with an externally applied voltage, the bands in the photon absorbing layer next to the barrier layer are flat or accumulated, and the flat part of the valence band edge of the photon absorbing layer lies below the flat part of the valence band edge of the contact layer and it also lies an energy of not more than $10kT_{op}$ above the valence band edge in any part of the barrier layer, where k is the Boltzman constant and T_{op} is the operating temperature.

15. A photo-detector according to claim 14 wherein the photon absorbing layer has a typical thickness of 1-10μ and doping of $n < 10^{16}$ cm^{-3}.

16. A photo-detector according to claim 14 wherein the middle barrier layer has a thickness of between 0.05 and 1μm.

17. A photo-detector according to claim 14 wherein the barrier layer is doped n-type, typically $n < 5 \times 10^{16}$ cm^{-3}, and a p-n junction is formed between said barrier layer and a p-type, $p < 5 \times 10^{18}$ cm^{-3}, contact layer.

18. A photo-detector according to claim 14 wherein the barrier layer is doped p-type, typically $p < 5 \times 10^{16}$ cm^{-3} and a p-n junction is formed between said barrier layer and an n-type δ–doping layer typically with $5 \times 10^{10} < n < 10^{12}$ donors cm^{-2}, included at the edge of the photon absorbing layer next to the barrier layer.

19. A photo-detector according to claim 14, wherein the photon absorbing layer is InSb or an $In_{1-x}Al_xSb$ alloy.

20. A photo-detector according to claim 14 wherein the contact layer is InSb or an $In_{1-x}Al_xSb$ alloy.

21. A photo-detector according to claim 14 wherein the middle barrier layer is an $In_{1-x}Al_xSb$ alloy.

22. A photo-detector according to claim 14 in which the n-type photon absorbing layer is terminated by a highly n-doped terminating layer, typically with $3 \times 10^{17} < n < 3 \times 10^{18}$ donors cm^{-3}, and with thickness 0.5 - 4μ, so that the valence band edge of said highly n-doped terminating layer lies below that of the n-type photon absorbing layer.

23. A photo-detector with a reduced G-R noise, comprising a sequence of a n-type contact layer, a middle barrier layer and a p-type photon absorbing layer, said middle barrier layer having an energy bandgap significantly more than and preferably at least twice that of the photon absorbing layer, there being no layer with a narrower energy bandgap than that in the photon-absorbing layer,

wherein under flat band conditions the conduction band edge of the contact layer lies above its own valence band edge or above the valence band edge of the barrier layer by significantly more than and preferably at least twice the bandgap energy of the photon absorbing layer and, wherein when biased with an externally applied voltage, the bands in the photon absorbing layer next to the barrier layer are flat or accumulated, and the flat part of the conduction band edge of the photon absorbing layer lies above the flat part of the conduction band edge of the contact layer and it also lies an energy of not more than $10kT_{op}$ below the conduction band edge in any part of the barrier layer, where k is the Boltzman constant and T_{op} is the operating temperature.

24. A photo-detector according to claim 23 wherein the photon absorbing layer has a typical thickness of 1-10μ and doping of $p < 10^{16}$ cm^{-3}

25. A photo-detector according to claim 23 wherein the barrier layer is doped p-type, typically $p < 5 \times 10^{16}$ cm^{-3}, and a p-n junction is formed between said barrier layer and a n-type, $n < 5 \times 10^{18}$ cm^{-3}, contact layer.

26. A photo-detector according to claim 23 wherein the barrier layer is doped n-type, typically $n < 5 \times 10^{16}$ cm^{-3} and a p-n junction is formed between said barrier layer and a p-type δ–doping layer typically with $5 \times 10^{10} < p < 10^{12}$ acceptors cm^{-2}, included at the edge of the photon absorbing layer next to the barrier layer.

27. A photo-detector according to claim 23 wherein the barrier layer is low-doped n-type, typically $n < 10^{15}$ cm^{-3}, and a p-n junction is formed between said barrier layer and the p-type photon absorbing layer.

28. A photo-detector according to claim 23 in which the p-type photon absorbing layer is terminated by a highly p-doped terminating layer, typically with $3 \times 10^{17} < p < 3 \times 10^{20}$ acceptors cm^{-3}, and with thickness 0.5 - 4μ, so that the conduction band edge of the highly p-doped terminating layer lies above that of the p-type photon absorbing layer

29. A photo-detector comprising stacked detector sub-units as in claim 1, claim 14, claim 23 or a combination thereof, in which each detector sub-unit may have a different cut-off wavelength.

30. An array of identical detectors in which each detector is as in claim 1 or as in claim 14, or as in claim 23 and is connected to a silicon readout circuit by an indium bump.

31. An array of identical detectors in which each detector may be sensitive to more than one wavelength band as in claim 13, or as in claim 29, and in which each detector is connected to a silicon readout circuit using one indium bump or using one indium bump per detector sub-unit.